MINERALIZATION OF BACTERIA IN TERRESTRIAL BASALTIC ROCKS: COMPARISON WITH POSSIBLE BIOGENIC FEATURES IN MARTIAN METEORITE ALH84001. K. L. Thomas-Keprta[1], D. S. McKay[2], S. J. Wentworth[1], T. O. Stevens[3], A. E. Taunton[4], C. C. Allen[1], E.K. Gibson Jr.[5], and C.S. Romanek[6]; [1]Lockheed Martin, Mail Code C-23 NASA/JSC, Houston, TX 77058, USA (KThomas@EMS.JSC.NASA.GOV), [2]Mail Code SN, NASA/JSC, Houston TX 77058, USA, [3]Battelle, Pacific Northwest Laboratory, P.O. Box 999, Richland WA 99352, USA, [4]Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville AR 72701, USA, [5]Mail Code SN4, NASA/JSC, Houston TX 77058, USA, [6]SREL, Drawer E, University of Georgia, Aiken SC 29802, USA.

The identification of biogenic features altered by diagenesis or mineralization is important in determining whether specific features in terrestrial rocks [e.g., 1,2] and in meteorites may have a biogneic origin [3]. Unfortunatley few studies have addressed the formation of biogenic features in igneous rocks, which may be important to these phenomena, including the controversy over possible biogenic features in basaltic martian meteorite ALH84001 [3]. To explore the presence of biogenic features in igneous rocks, we examined microcosms growing in basaltic small-scale experimental growth chambers or microcosms. Microbial communities were harvested from aquifers of the Columbia River Basalt (CRB) group and grown in microcosm containing unweathered basalt chips and groundwater [technique described in 4]. These microcosms simulated natural growth conditions in the deep subsurface of the CRB, which should be a good terrestrial analog for any putative martian subsurface ecosystem that may have once included ALH84001 [9].

Inoculated, fresh (control), and sterile solution rock chips were examined with a high resolution Philips XL 40 field emission gun scanning electron microscope (FEGSEM) and a JEOL 2000 FX transmission electron microscope (TEM). FEGSEM samples were coated with ~2-5 nm of Au-Pd conductive coating. Uncoated microorganisms were also examined in the TEM at 160 kV.

We examined over 30 surfaces of rock chips from the inoculated basaltic microcosms. A detailed study of five chips of uninoculated basalt chips revealed no cell-like forms or appendages. The inoculated chips displayed three dominant morphological types of forms which we interpret as microorganisms: Type 1: oval shaped (coccobacillus) form with a smooth surface texture which ranged from ~1-2.5 μm in length and slightly less in width. These organisms are composed chiefly of Fe, Mn, and O with minor elements including P. Type 2: a similarly shaped coccobacillus form in the same size range but with a textured surface composed of thousands of thin (~2-5 nm diameter) interwoven filaments composed mainly of Fe and O as ferrihydrite, an Fe^{+3} hydroxide with minor elements including P. Type 1 and 2 organisms are significantly mineralized; both types display organisms which appear hollow. It is not clear if the formation of a mineralized shell was a replacement for the original cell wall or a coating that developed external to the cell. Nevertheless, there was no evidence for the preservation of any ultrastructure, such as the cell wall. Type 3: tubular (bacillus or rod) forms to which a single appendage may be attached at one end. They range from ~0.30 -2.4 μm in the longest direction without appendage. Micro-colonies of bacillus forms are frequently observed embedded in biofilm. Type 3 organisms are composed mainly of C, O, Na with minor P, S, Cl; they are unmineralized cells. All three types of organisms contain minor P whether they are mineralized or not. In addition to the organisms, we observed attached and unattached filaments. Filaments are generally longer and thinner that organisms; they have distinctive tubular morphologies. Attached filaments are similar in composition to the Type 3 unmineralized cells. Unattached filaments are composed of ferrrihydrite and other minor elements inlcuding P; their composition is similar to the Type 2 organisms. Some unattached filaments are hollow (Fig 1). We believe that these unattached filaments are mineralized cellular appendages because they are not present in the uninoculated control microcosms so we conclude that they were likely produced by biological mechanisms. In addition, the presence of P indicates that these filaments are most likely biogenic. If so, it is clear that the mineralization of bacteria is not necessarily restricted to the main body of the organisms; much smaller appendages can also be preserved. The present observations suggest that microfossils in basaltic rocks may contain little carbon, may lack evidence of cellular ultrastructure, and may include mineralized sub-cellular appendages. The presence of abundant biofilm may also serve as a substrate upon which minerals may be deposited. If so, it is likely that mineralized web-like biofilms may also be preserved and suggest previous biogenic activity.

Here we present new size measurements and photomicrographs comparing the putative martian fossils to biogenic material in the CRB microcosms (Fig. 1). The range of size and shapes of the biogenic features on the CRB microcosm chips overlaps with and is similar to those on ALH84001 chips. Although this present work does not provide evidence for the biogenicity of ALH84001 features, we believe that based on criteria of size, shape, and general morphology, a biogenic interpretation for the ALH84001 features remains plausible.

References: [1] Hoffman H. J. and Schopf J. W. (1983) in *Earths Earliest Biosphere. Its Origin and Evolution*. (J.W. Schopf, ed.), Princeton Univ. Press. [2] Ferris F. G. et al. (1986) *Nature, 320,* 609. [3] McKay D. S. et al.

(1996) *Science*, *273,* 924. [4] Stevens T. O. and McKinley J. P. (1995) *Science*, *270*, 450.